9.6 A COMPARISON OF RESULTS OBTAINED FROM FOIL CHAFF CLOUDS AT 69° NORTHERN LATITUDE DURING WINTER, SUMMER AND AUTUMN

H. U. Widdel

Max-Planck-Institut für Aeronomie
Postfach 20, 3411 Katlenburg-Lindau, FRG

U. von Zahn

Physikalisches Institut der Universität Bonn
Nussallee 12, D-5300 Bonn 1, FRG

Results from high-resolution foil chaff experiments flown during the campaigns MAP/WINE (December 83 - February 84), MAC/SINE (June/July 87) and Epsilon (October/November 87) at Andenes (Northern Norway) are compared to each other and the differences in wind direction and wave activity during the different seasons are worked out.

Table 1. Types of Chaff.

Maximum height (km)	Thickness (μm)	width: (mm)	length (mm)	Mass-over area ratio (g/m^2)	Designation:
≤85	10	8,5	24	13,6	heavy(H)
≤93	2,5	9	24	3,4	light(L)
≤96	1,5	8	24	2,37	super hight(SL)
≤102	1	8	24	1,7	extra light(EL)

The foil chaff method is best suited for the investigation of fine structures of atmospheric motions in the middle atmosphere. The type of chaff to be used for such purposes should be selected and matched to the height at which such investigations are to be performed. The 1 micrometer thick material is a new development rather difficult to handle and gets very close to the physical limit of height up to which the chaff method can sensibly be used at all (108 km depends upon latitude and season).

Table 2. Summary of Data Available for Analysis.

Season	Campaign	Period	Number of flight per kind of chaff	
WINTER:	MAP/WINE	Dec. 83-Feb. 84	H:2 L:14(16)	SL:- EL:-
SUMMER:	MAC/SINE	Jun. 87-July 87	H:5 L:17	SL:- EL:-
SUMMER:	MAC/Sodium	Jun. 88-July 88	H:- L:-	SL:3 EL:7
AUTUMN:	MAC/EPSILON	Oct. 87	H: L:3(+1)	SL:4 EL:-

Height coverage:

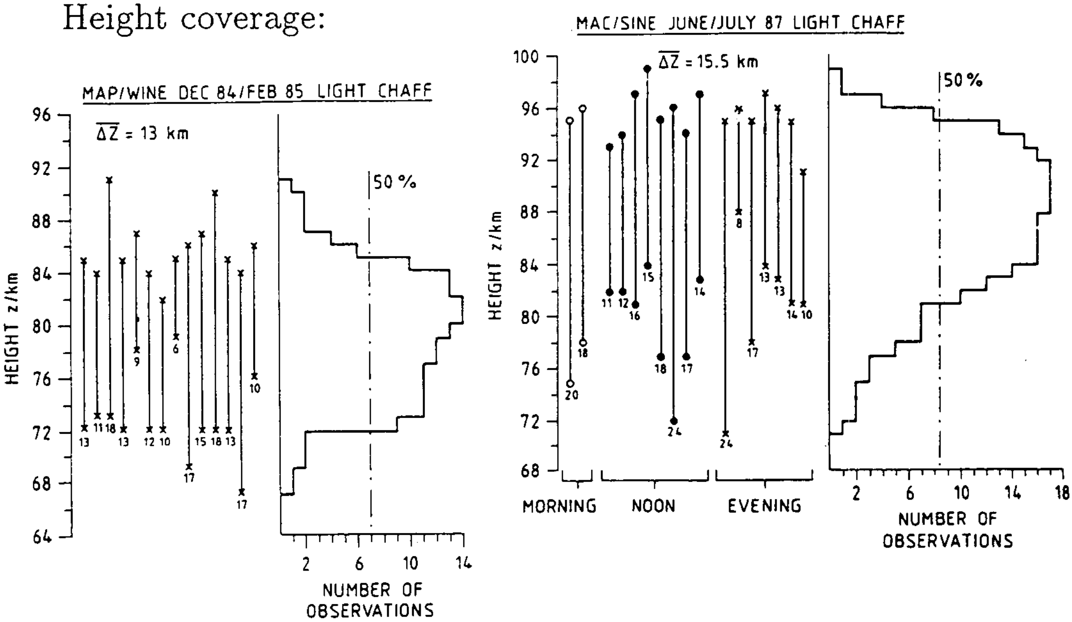
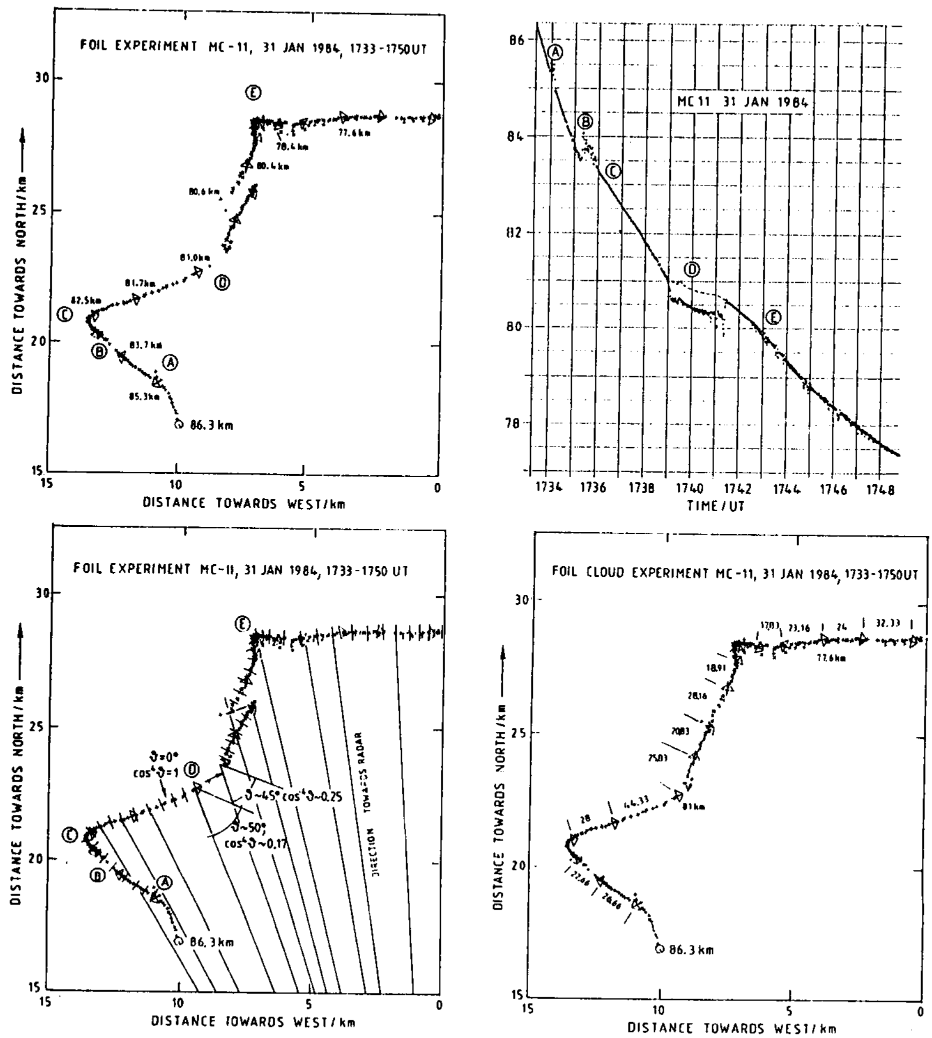


Figure 1. The histograms show that the height coverage of measurements was different in winter and summer. This was caused by different performance of the rockets. The average height coverage of 15 km during summer agrees quite well with predictions obtained from a theoretical description of the flight behavior of foil chaff.

Figure 2. (Following page) Example for a winter measurement. All data raw, uncorrected radar tracking data. (a) Projection of the trajectory onto the earth's surface (to be read like a map, north at top). Note offset at "D" marks at 1 minute interval. (b) Height versus time plot which shows some irregularities (marked A to E). These irregularities (height jumps of order 500 m) occur when the direction changes (see Figure at left). (c) Explanation of the jump seen at point "D" and an example how to correct it. The foils fly with their longitudinal axis perpendicular to the direction of fall and to the direction of drift in the wind. The return power received by the radar varies with the fourth power of the angle between the radar wave polarization plane and the dipole's longitudinal axis. The could had a certain vertical extent (~500 m) and was oriented "oblique" in space as the result of several shears it passed. At "D" the orientation of the foils change and the radar moves to the bottom end of the cloud. (d) "Repaired" trajectory. Note that the drift velocity is "modulated (~5 m/s). (e) Vertical velocities of air derived from the chaff data using independent temperature and density data (falling sphere flown close in time to launch of chaff). Note that disturbances A to D are seen at or close to the crest of an upgoing wave motion. They were never seen at maximum downward motion. Dotted lines take into account roll-in of the chaff results suggest that it did not occur (inner curve).


FOIL EXPERIMENT MC-11, 31 JAN 1984, 1733-1750UT
DISTANCE TOWARDS NORTH/km
DISTANCE TOWARDS WEST/km
86.3 km
MC 11 31 JAN 1984
TIME/UT
FOIL EXPERIMENT MC-11, 31 JAN 1984, 1733-1750 UT
DIRECTION TOWARDS RADAR
FOIL CLOUD EXPERIMENT MC-11, 31 JAN 1984, 1733-1750UT
77.6km
81km

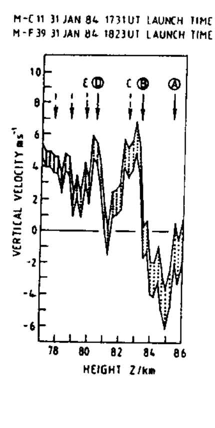
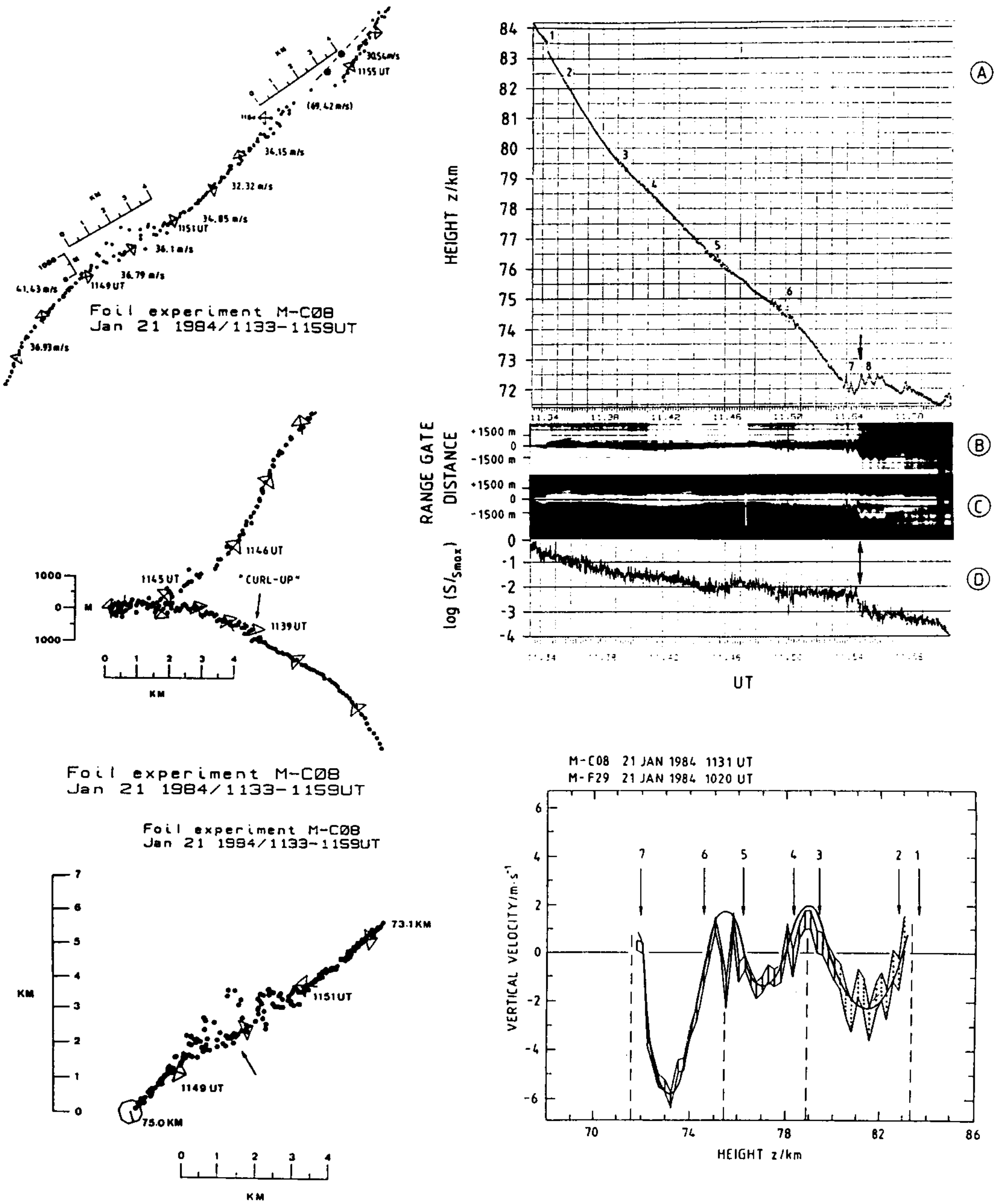

M-C 11 31 JAN 84 1731UT LAUNCH TIME
M-F 39 31 JAN 84 1823UT LAUNCH TIME
VERTICAL VELOCITY ms⁻¹
HEIGHT Z/km

Figure 2.

Figure 3. (Following page) Winter data: second example suggesting quasi-acoustic disturbances connected with breaking of waves. Upper right: height vs time plot (A) with echo record (B,C) and variation of radar cross section (D). One notes that the plot becomes transiently noisy at fairly regular intervals (~ 4 - 5 min) and that the cloud is eventually destroyed by a violent event at 72 km. Before that, quasi-regular oscillations are seen and the echo record tells that these were motions in the cloud which did not change its size. The trajectory map was broken for reasons of clearer visibility of details. Middle left: the trajectory is shown from z = 81.5 km to 2 = 75.2 km. The disturbances No. 3 and 4 are hidden in the loop and manifest themselves as "curl-ups", No. 5 as some data scatter after having passed the loop, but No. 6 (and 7) are clearly seen as scatter across the trajectory (left, top). An enlargement (bottom, left) plotted at a higher data rate (1 per second) shows that No. 6 comprised in fact two consecutive events separated by only a short time (arrow). Explanation is that the foils behave like Rayleigh disks and were turned out of orientation by an acoustic wave and the scatter represents the true extension of the foil cloud as is supported by the echo records. Entering the heights in which the noise was observed into the plot of vertical motions one notes that they are located about symmetrically to the crests of upgoing motions. Assuming acoustic disturbances caused by the breaking of waves, this can be understood: in contrast to ocean waves, there is no significant change in acoustic impedance between medium and wave and the noise is seen on both sides of the wave.



Foil experiment M-C08
Jan 21 1984/1133-1159UT
1155 UT
1151UT
1149UT
1146UT
1145UT
"CURL-UP"
1139UT
KM
73.1KM
75.0KM
HEIGHT z/km
RANGE GATE DISTANCE
log (S/S_max)
UT
A
B
C
D
M-C08 21 JAN 1984 1131 UT
M-F29 21 JAN 1984 1020 UT
VERTICAL VELOCITY/m·s⁻¹
HEIGHT z/km

Figure 3.

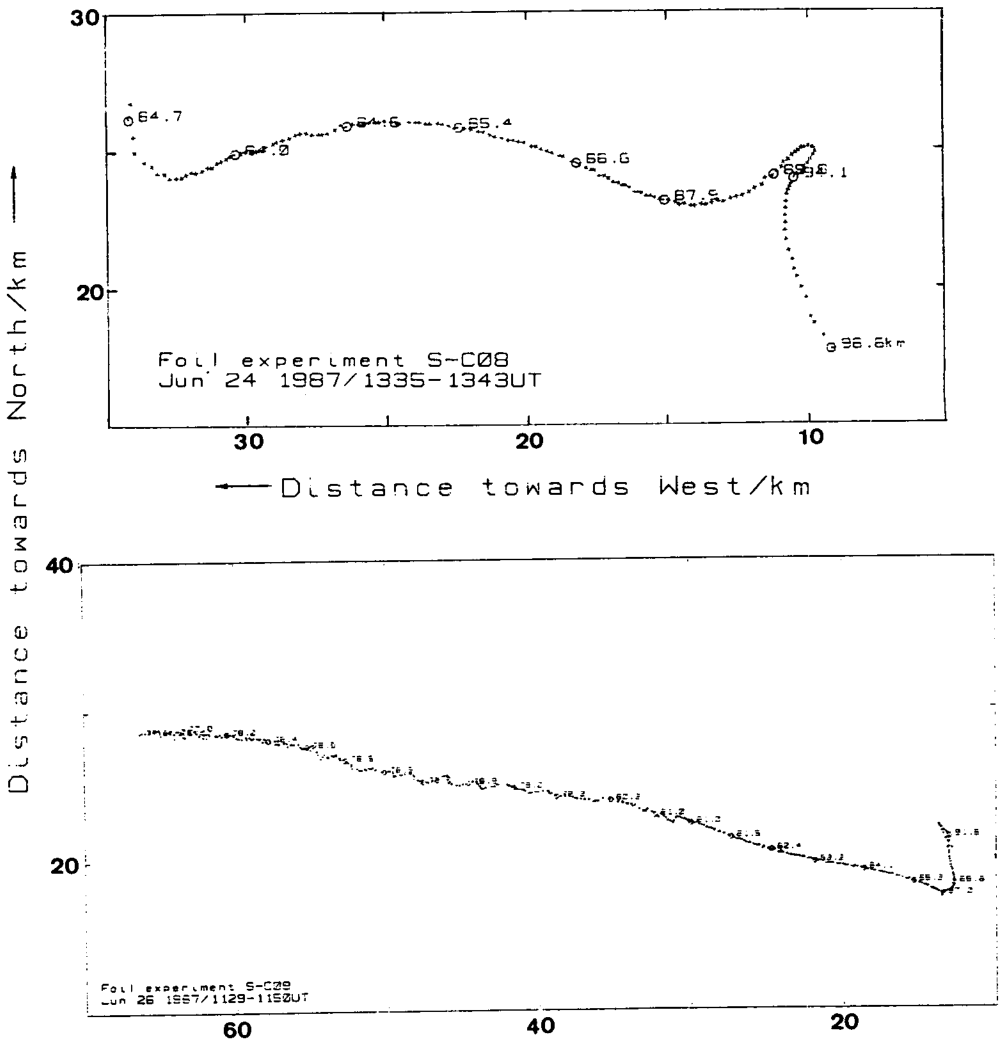


Figure 4. Summer measurement. No wind corners were observed below 88 km but rather uneventful drifts towards west (or south) in which strong turbulence and/or "billows" (vortices) were imbedded. Upper figure: very rapid destruction of cloud below 84 km. Lower figure: "Billows show up below 81 km. Rapid destruction (disappearance of the radar echo within a few seconds) was a salient feature of the summer measurements.

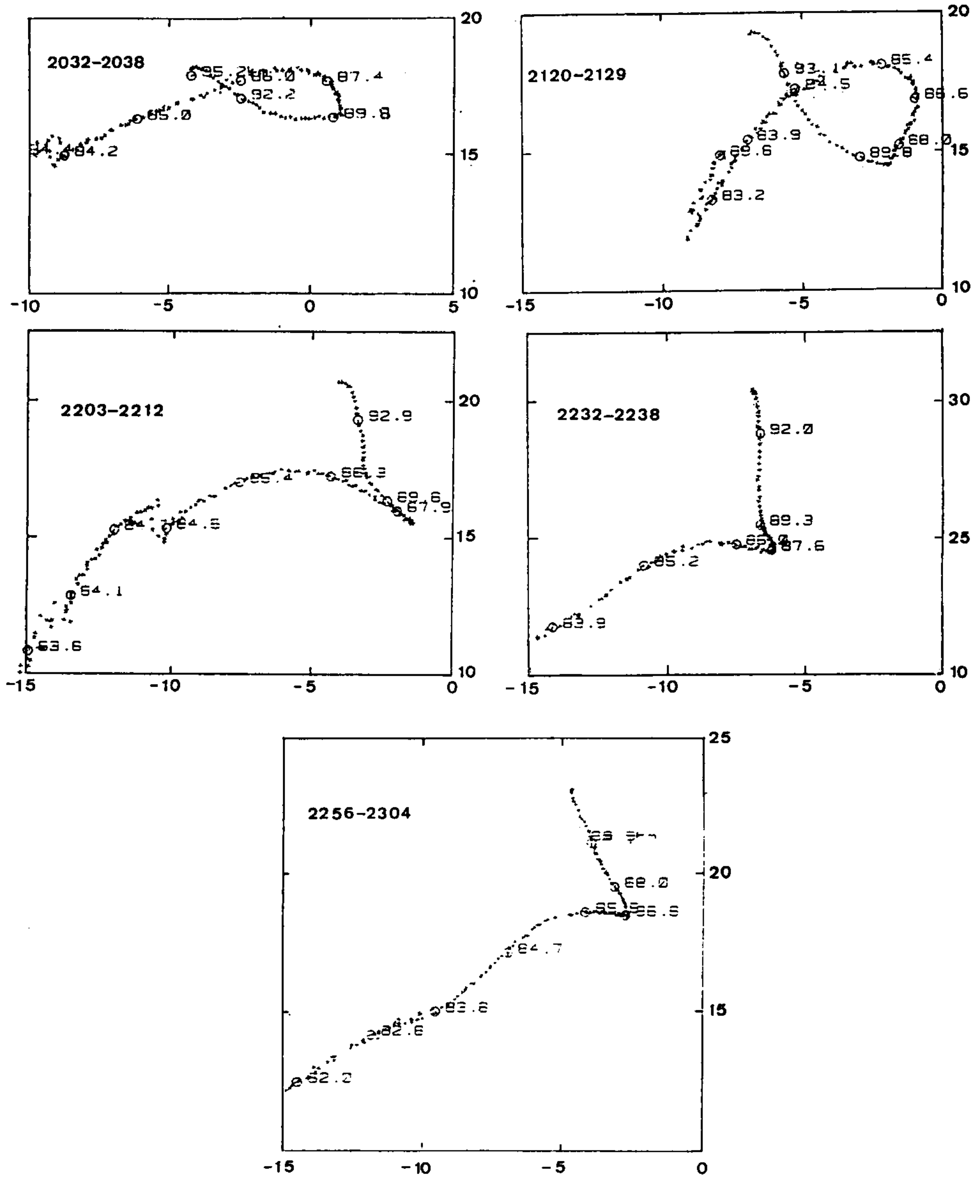


Figure 5. "Wind corners" were not seen during summer below 88 km, but above. Development of a "wind corner" shortly before local midnight between 88 and 89 km and its decay (15 July 1988). Note degradation of tracking data (resp. destruction of cloud flight 2120 UT) at the 83 - 84 km level caused by turbulence.

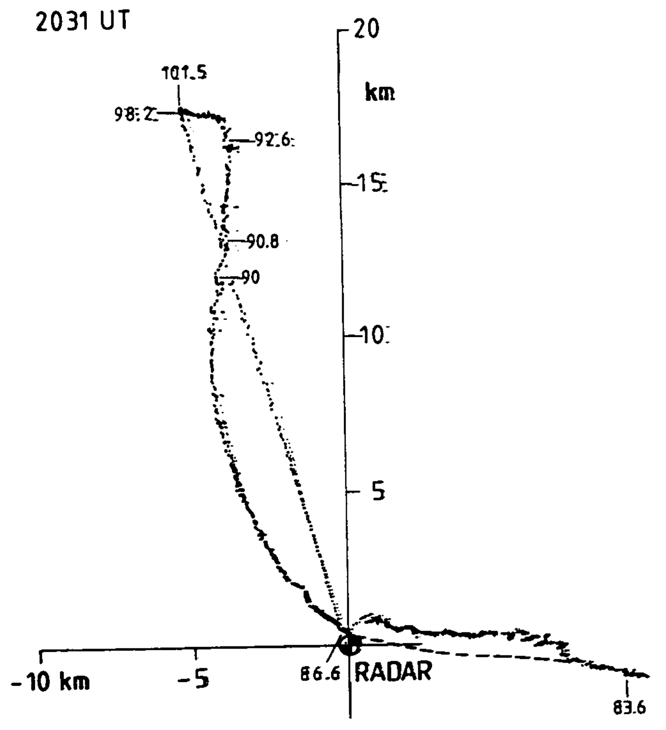


Figure 6. Second example for a development of a wind corner (24 June 1988) observations made with 1.5 μm and 1 μm chaff. 2031: No wind corner (note difference to 5!).

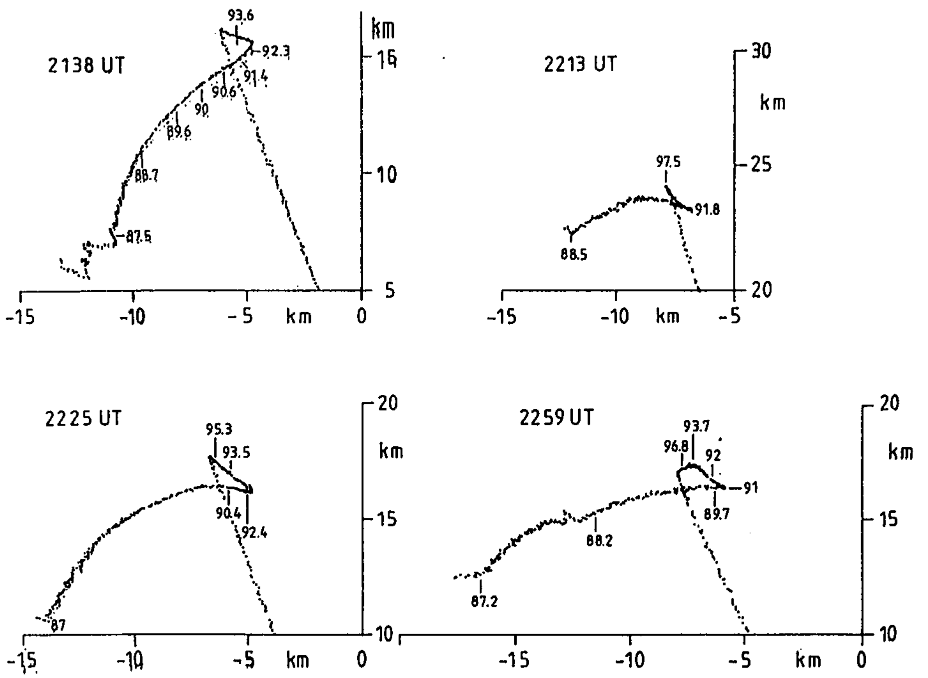


Figure 7. Development of wind corner which subsides. Note destruction of cloud at the 87-88 km level. Comparing 5 to 7 it looks as if the formation of wind corners is associated with a region of strong turbulence 4 - 6 km lower in height.